

REMARKS**Rejections Under 35 U.S.C. §103(a)**

The examiner rejected claims 1-7, 15-16, and 22-23 under 35 U.S.C. §103(a) as being unpatentable over Feller in view of Tsai et al.; claims 8-11, 17-20, and 24-25 under 35 U.S.C. §103(a) as being unpatentable over Feller in view of Tsai and further in view of Kaufman et al.; claim 12 under 35 U.S.C. §103(a) as being unpatentable over Feller in view of Tsai and further in view of Grumbine et al.; and claims 13, 14, 21, and 26 under 35 U.S.C. §103(a) as being unpatentable over Feller and further in view of Tsai and Payne. Applicants canceled claims 1-14 and 24-26, obviating the need to respond to rejections of those claims, and amended the remaining claims to further distinguish the claimed slurry from those that the cited references describe. These amended claims define slurries that would not have been obvious in view of those described in the cited references, and are thus patentable over them.

To appreciate the significance of applicants' invention, one must consider the problem that gave rise to it. As explained in the Background of the Invention section of applicants' application, when using a single or dual damascene process to make a copper interconnect for a semiconductor device, excess material used to form the barrier and copper layers for the interconnect must be removed from the surface of a dielectric layer. Slurries currently used to remove those materials may do so at different rates, when the dielectric layer is made from certain materials. As a result, the surface of one material may be recessed below, or raised above, the other materials' surfaces. When, for example, a

copper layer is recessed below the barrier and dielectric layers, after it is polished, the device may be susceptible to shorts when subsequently deposited copper fills the recess. If the copper layer is raised above the other layers, protruding copper structures may adversely affect device performance.

Prior to applicants' invention, a need existed for a slurry that enabled a copper layer, a barrier layer, and a dielectric layer – particularly one containing a carbon doped oxide – to be polished at similar rates. The slurries defined by the pending claims, i.e., claims 15-23, enable these materials to be polished at similar rates, thus reducing copper "dishing" and "fangs" that often result when currently available slurries are used to polish them.

The examiner rejected the remaining independent claims, i.e., claims 15 and 22, based on the combination of Feller and Tsai. Applicants amended claim 15 to define a slurry that includes the following components:

between about 0.01 mole and about 0.1 mole per liter of a citric acid salt;
between about 1% and about 20% by volume of a silica based abrasive;
between about 0.0004 and about 2 moles per liter of an oxidizer; and
a water solvent.

Support for this amendment appears in Example 1 at page 11, lines 3-8, which specifies a mixture that includes these components and "a water solvent." As the examiner acknowledged, neither Feller nor Tsai describes a slurry that includes these components in these amounts. Feller (a patent assigned to this application's assignee) describes a slurry that includes 0.25 molar potassium fluoride, 0.5% by weight silica, 14.25 grams per liter citric acid, and 8.1 grams

per liter potassium citrate. (See Feller at column 6, lines 3-6.) Water serves as an oxidant for the aluminum film that this slurry will polish.

Applicants' amended claim 15 specifies an oxidizer and a water solvent. Unlike Feller's slurry, in which the water solvent performs the oxidizing function, the claimed slurry requires an oxidizer that is separate from the water solvent. Feller's slurry, which includes water without a separate oxidizing component, is like the slurry of applicants' Example 2. That slurry, like Feller's, does not include a separate oxidizer. Note that this slurry removed tantalum (which formed the barrier layer) and a SiOF dielectric layer over 10 times faster than it removed a copper layer. Applicants' Example 2 thus shows that a slurry like Feller's, which lacks an oxidizing component that is separate from the water solvent, is incapable of polishing barrier, dielectric, and copper layers at similar rates.

Applicants' claimed slurry, on the other hand, includes between about 0.0004 and about 2 moles per liter of an oxidizer in addition to a water solvent. As applicants' Examples 1 and 3 demonstrate, such a slurry enables a conventional chemical mechanical polishing process to remove barrier, dielectric, and copper layers at similar rates. Those examples specify a slurry with 0.38 grams of a 30% H_2O_2 solution per liter of slurry (equivalent to 0.0033 molar) in addition to a water solvent. The Example 1 slurry removed tantalum at about 590 angstroms per minute, copper at about 694 angstroms per minute, and SiOF at about 610 angstroms per minute. The Example 3 slurry removed tantalum at

about 638 angstroms per minute, copper at about 625 angstroms per minute, and SiOF at about 660 angstroms per minute.

Neither Feller nor Tsai offers any suggestion that would have motivated those skilled in the art to modify the slurry Feller describes to add to it "between about 0.0004 and about 2 moles per liter of an oxidizer" in addition to a water solvent. Neither reference mentions that Feller's slurry -- designed to polish aluminum and lacking a separate oxidizer -- will remove barrier and dielectric layers over 10 times faster than it removes copper. Nor does either reference identify any benefit that may be derived, when modifying Feller's slurry by adding to it "between about 0.0004 and about 2 moles per liter of an oxidizer," in addition to the water solvent. It follows, of course, that neither reference suggests that altering that slurry in that way may convert it into one that is capable of removing barrier, dielectric, and copper layers at similar rates. For these reasons, neither Feller nor Tsai would have motivated one skilled in the art to change Feller's slurry, which removes barrier and dielectric layers 10 times faster than it removes copper, to enable it to remove these materials at similar rates.

Because neither Feller nor Tsai offers any suggestion that would have motivated one skilled in the art to modify Feller's slurry, which lacks a separate oxidizer in addition to the water solvent, to generate the slurry of amended claim 15, the claim 15 slurry would not have been obvious in view of these references' combination. Accordingly, applicants respectfully request the examiner to allow amended claim 15 over the combination of Feller and Tsai. Because claims 16-

21 depend upon amended claim 15 (either directly or indirectly), the slurries of these dependant claims are patentable over this combination of references for the same reasons that amended claim 15 is patentable over that combination. Applicants respectfully request the examiner to also allow these dependent claims to issue.

Applicants amended claim 22 to specify a slurry that comprises a mixture of:

about 14.7 grams per liter of a citric acid salt;
between about 4.4% and about 8.8% by volume of a silica based
abrasive; and

about .38 grams per liter of a 30% H_2O_2 solution.

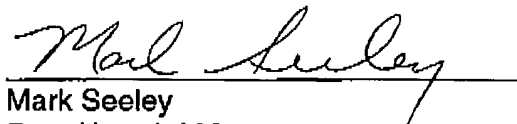
Support for this amendment appears in applicants' Example 1 at page 11, lines 3-8, and in applicants' Example 4 at page 12, lines 2-4, which specifies 4.4 volume % fumed silica in place of Example 1's 8.8 volume % of a precipitated silica abrasive. The slurry of amended claim 22 is thus like those of applicants' Examples 1, 3, 4, and 5. As mentioned above, these examples demonstrate that the slurry of amended claim 22 removes barrier, dielectric, and copper layers at similar rates.

Feller does not describe a slurry that includes these components. Nor does Feller offer any reason to modify the slurry it describes to generate one with these ingredients. Tsai cannot compensate for Feller's deficiency because that reference, like Feller, fails to provide any reason why it may be beneficial to convert Feller's slurry into the slurry of amended claim 22. Because neither

reference suggests any advantage to modifying Feller's slurry to create the slurry of amended claim 22, their combination would not have motivated one skilled in the art to do so. It necessarily follows that the claim 22 slurry would not have been obvious in view of these references' combination. For that reason, applicants respectfully request the examiner to allow amended claim 22, and its dependent claim 23, over the combination of Feller and Tsai – in addition to allowing claims 15-21 over that combination of references.

Respectfully submitted,

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**VERSION OF AMENDED CLAIMS WITH
MARKINGS TO SHOW CHANGES MADE**

15. (Amended) A slurry for polishing a barrier layer comprising a mixture of:
- between about 0.01 mole and about 0.1 mole per liter of a citric acid salt;
 - between about 1% and about 20% by volume of a silica based abrasive;
 - and
 - between about 0.0004 and about 2 moles per liter of an oxidizer; and
 - a water solvent.
22. (Amended) A slurry for polishing a barrier layer that serves to isolate a copper layer from a dielectric layer comprising a mixture of:
- ~~between about 0.01 mole and about 0.1 mole~~ 14.7 grams per liter of a citric acid salt ~~selected from the group consisting of potassium citrate and ammonium citrate;~~
 - between about 4% 4.4% and about 20% 8.8% by volume of a silica based abrasive; and
 - ~~between about 0.0004 and about 2 moles~~ .38 grams per liter of a 30% H₂O₂ solution ~~an oxidizer.~~
23. (Amended) The slurry of claim 22 wherein the mixture includes about 8.8% by volume of a precipitated silica abrasive, has a pH that is ~~greater than~~ about 7.04, and wherein the citric acid salt is potassium citrate.